



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification 7 : E21B 29/00, B21D 17/04, 39/04</p>	<p>A2</p>	<p>(11) International Publication Number: <b>WO 00/37767</b> (43) International Publication Date: 29 June 2000 (29.06.00)</p>												
<p>(21) International Application Number: PCT/GB99/04248 (22) International Filing Date: 22 December 1999 (22.12.99) (30) Priority Data:  <table border="0"> <tr> <td>9828234.6</td> <td>22 December 1998 (22.12.98)</td> <td>GB</td> </tr> <tr> <td>9900835.1</td> <td>15 January 1999 (15.01.99)</td> <td>GB</td> </tr> <tr> <td>9923783.6</td> <td>8 October 1999 (08.10.99)</td> <td>GB</td> </tr> <tr> <td>9924189.5</td> <td>13 October 1999 (13.10.99)</td> <td>GB</td> </tr> </table> <p>(71) Applicants: PETROLINE WELLSYSTEMS LIMITED [GB/GB]; Offshore Technology Park, Claymore Drive, Bridge of Don, Aberdeen AB23 8GD (GB). ASTEC DEVELOPMENTS LIMITED [GB/GB]; ODS Building, Greenbank Crescent, East Tullis, Aberdeen AB12 3BG (GB). (72) Inventors: METCALFE, Paul, David; North Wing, Bucklerburn Steading, Peterculter AB14 0NP (GB). SIMPSON, Neil, Andrew, Abercrombie; Burn of Daff Farm, Downies, Portlethen, Aberdeen AB12 4QX (GB). (74) Agents: McCALLUM, William, Potter et al.; Cruikshank &amp; Fairweather, 19 Royal Exchange Square, Glasgow G1 3AE (GB).</p> </p>		9828234.6	22 December 1998 (22.12.98)	GB	9900835.1	15 January 1999 (15.01.99)	GB	9923783.6	8 October 1999 (08.10.99)	GB	9924189.5	13 October 1999 (13.10.99)	GB	<p>(81) Designated States: AU, BR, CA, NO, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published <i>Without international search report and to be republished upon receipt of that report.</i></p>
9828234.6	22 December 1998 (22.12.98)	GB												
9900835.1	15 January 1999 (15.01.99)	GB												
9923783.6	8 October 1999 (08.10.99)	GB												
9924189.5	13 October 1999 (13.10.99)	GB												
<p>(54) Title: PROFILE FORMATION</p> <p>(57) Abstract</p> <p>A method of forming a profile (10) in a section of tubing (12) comprises: providing an expander device (14) having at least one radially extendable expander member (22); positioning the device (14) at a predetermined location in the tubing (12); and extending the member (22) to deform the tubing (12) to create a profile (10).</p> <div data-bbox="1120 1050 1380 1764"> </div>														

BEST AVAILABLE COPY

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon	KR	Republic of Korea	PL	Poland		
CN	China	KZ	Kazakhstan	PT	Portugal		
CU	Cuba	LC	Saint Lucia	RO	Romania		
CZ	Czech Republic	LI	Liechtenstein	RU	Russian Federation		
DE	Germany	LK	Sri Lanka	SD	Sudan		
DK	Denmark	LR	Liberia	SE	Sweden		
EE	Estonia			SG	Singapore		

PROFILE FORMATION

This invention relates to downhole profile formation, and in particular the formation or provision of profiles in cased boreholes. The invention also relates to cutting or otherwise forming casing.

5        In the oil and gas exploration and production industries, subsurface hydrocarbon-bearing formations are accessed via drilled boreholes lined with steel tubing, known as casing. The casing will often define profiles, typically annular recesses or annular restrictions, to  
10       facilitate the location and mounting of tools and devices in the borehole. The profiles are formed in the casing before it is run into the borehole, and are positioned in the string of casing at predetermined locations. This places restrictions on the subsequent placement of tools  
15       and devices in the bore, and the original profile locations may prove not to be appropriate as the well is developed. Further, different tool manufacturers utilise different profiles, and once the casing is in place an operator may be committed to obtaining tools from a single source  
20       throughout the life of the well.

It is among the objectives of embodiments of the invention to obviate and mitigate these difficulties.

According to a first aspect of the present invention there is provided a method of forming a profile in a

section of tubing, the method comprising:

providing an expander device having at least one radially extendable expander member;

5 positioning the device at a predetermined location in a section of tubing;

extending the member to deform the tubing at said location to create a profile therein.

The invention facilitates the formation of a profile at a desired location in a section of tubing, such that, for example, an operator is not constrained to utilising preformed profiles of particular configuration at fixed locations in the tubing.

The profile may take any appropriate form, including one or more annular recesses, one or more circumferentially spaced recesses, and a female thread. As such, the profile may permit or facilitate the location of tools or devices in the tubing at the profile location. Alternatively, the profile may serve as a reference point.

Preferably, the tubing is deformed by rolling expansion, that is an expander member is rotated within the tubing with a face in rolling contact with an internal face of the tubing. Such rolling expansion may cause compressive plastic deformation of the tubing and a localised reduction in wall thickness resulting in a subsequent increase in tubing diameter. Alternatively, where the tubing is constrained, for example by outer tubing or surrounding rock or cement, the tubing material may flow by virtue of the compressive plastic deformation

to create a groove or raised profile. The tubing expander may take any appropriate form, and the expander member may be mechanically or fluid pressure activated. Conveniently, the expander member is in the form of a roller, and may  
5 define a raised circumferential rib or other profile to provide a high pressure contact area and to create a profile in the tubing of a predetermined form. Preferably, the expander member is extended by application of fluid pressure. In the preferred form, the expander member is in  
10 the form of a roller having a tapered end and is operatively associated with an axially movable piston and cam or wedge, although in other embodiments the member may itself define a piston which is radially movable in response to internal expander tool pressure. Preferably,  
15 a plurality of expander members are provided, and most preferably a plurality of the expander members are radially extendable.

Preferably, the expander member is run into the tubing on a running string, which may be reelable, such as coil  
20 tubing. The running string may be rotated to create the profile, or a motor may be mounted in the running string to rotate the expander.

The tubing may be in the form of a riser tube, as used to connect an offshore platform, rig or ship to a subsea  
25 wellhead assembly. Alternatively, the tubing may be in the form of bore-lining tubing, such as casing or liner, or may be production tubing.

According to a second aspect of the present invention

there is provided a method of forming a profile in a section of tubing, the method comprising deforming a section of tubing by rolling expansion to create a profile therein.

5       According to another aspect of the present invention there is provided a method of providing a profile in a section of tubing, the method comprising:

          providing a ring of deformable material;

          providing an expander device having at least one  
10   radially extendable member;

          positioning the ring and the device at a predetermined location in a section of tubing;

          extending the member to deform the ring such that the ring engages the tubing at said location to create a  
15   profile therein.

          According to a further aspect of the present invention there is provided apparatus for providing a profile in a section of tubing, the apparatus comprising: a ring of deformable material; and an expander device having at  
20   least one radially extendable member, the device being locatable within the ring and the member being extendable to deform the ring into engagement with surrounding tubing to create a profile therein.

          These aspects of the invention offers additional  
25   advantages to the aspects of the invention described above. In certain applications it may be difficult to deform existing tubing, which would be the case with, for example, heavy gauge cemented casing or hardened tubing, and these

aspects of the invention obviate these difficulties by locating a ring in the casing. Further, the ring may provide a restriction in the tubing, which may be utilised as a "no-go" to locate tools and other devices in the tubing. The ring may be preformed to define any predetermined profile, for example a thread, lip, recess or wedge.

Preferably, the ring and the expander device are run into the tubing together. Most preferably, the expander member is profiled to provide a mounting for the ring.

Preferably, the ring is deformed to form an interference fit with the tubing, most preferably by increasing the diameter of a section of the ring. Most preferably, the ring is deformed by rolling expansion, that is an expander member is rotated within the ring with a face in rolling contact with an internal face of the ring. Such rolling expansion causes compressive plastic deformation or yield of the ring and a localised reduction in wall thickness resulting in a subsequent increase in ring diameter.

The ring may comprise a relatively ductile portion welded or otherwise connected to a relatively inflexible portion, the deformation of the ring being restricted to the relatively ductile portion.

The ring may carry grip banding or the like on an outer surface to facilitate secure location relative to the tubing. The grip banding may comprise relatively hard elements such as grit or balls formed of hard material such

as tungsten carbide.

According to yet another aspect of the present invention there is provided a method of providing a profile in a section of tubing, the method comprising deforming a  
5 ring of material by rolling expansion within a section of tubing such that the ring engages the tubing at said location to create a profile therein.

According to a still further aspect of the present invention there is provided a method of cutting a section  
10 of tubing, the method comprising:

providing a cutting device having at least one radially extendable rolling member defining a raised circumferential portion;

positioning the device at a predetermined location in  
15 a section of tubing;

extending the member to contact the tubing at said location and rotating the device to deform the tubing, the degree of deformation being such that the tubing is cut at said location.

20 This aspect of the invention may be used in many different applications, for example severing a riser which cannot be released from a wellhead assembly, or cutting a section of casing or liner.

Preferably, the cutting device is provided with a  
25 plurality of rolling members, which progressively compress the tubing wall and reduce the wall thickness thereof.

These and other aspects of the present invention will now be described, by way of example, with reference to the



accompanying drawings, in which:

Figure 1 is a schematic sectional view of a stage in a method of forming a profile in a section of tubing in accordance with an embodiment of an aspect of the present invention;

Figures 2 and 3 are schematic sectional views of stages in a method of providing a profile in a section of tubing in accordance with an embodiment of another aspect of the present invention;

Figures 4, 5 and 6 are schematic sectional views of stages in a method of providing a profile in a section of tubing in accordance with a second embodiment of said another aspect of the present invention; and

Figure 7 is a schematic sectional view of a stage in a method of cutting tubing in accordance with an embodiment of a further aspect of the present invention (on same sheet as Figure 1).

Reference is first made to Figure 1 of the drawings, which is a schematic sectional view of a stage in a method of forming a profile 10 a section of downhole tubing 12 in accordance with an embodiment of an aspect of the present invention. In this example the tubing 12 is in the form of bore-lining casing. The profile 10 is useful for locating tools and devices in the tubing 12 and is formed using an expander device 14 as will be described.

The expander device 14 is run into the tubing 12 on a tool string 18 and comprises a body 20 carrying three radially extendable rollers 22, each defining a raised

central rib 24. The rollers 22 have tapered ends and are mounted on cones coupled to a piston which is axially movable in response to pressure applied to the interior of the expander body 20 via the tool string 18.

5 In use, the device 14 is run into the tubing 12 with the rollers 22 in the retracted configuration. Once at a desired location in the tubing 12 the device 14 is activated by applying pressure through the string 18, to urge the rollers 22 radially outwardly. At the same time,  
10 the string is rotated from surface, or from an appropriate downhole motor, such that the rollers 22 are in rolling contact with the inner wall of the tubing 12 and subject the tubing wall to pressure sufficient to induce compressive yield and a localised reduction in wall  
15 thickness. This in turn causes the diameter of the tubing to increase, and creates the profile 10.

Profiles may be provided at any location in the tubing 12 which may accommodate the necessary deformation. However, in some situations, it may be difficult to create  
20 the necessary deformation; cemented heavy gauge casing may be difficult to deform to any significant extent. In this case, a profile may be provided in the tubing, as will now be described with reference to Figures 2 and 3 of the drawings.

25 In other embodiments of this aspect of the invention, particularly when the tubing 12 is constrained within a bore or other tubing or by surrounding rock or cement, where it not possible for the tubing diameter to expand,

the deformation mechanism is somewhat different in that the material of the tubing subject to compressive plastic deformation or yield will tend to flow to create the profile, without the creation of a corresponding "bulge" in the outer wall of the tubing.

Figure 2 is a schematic sectional view of a stage in a method of providing a profile 30 in a section of tubing 32 in accordance with an embodiment of another aspect of the present invention. The profile 30 is formed in a ring 34 which is located in the tubing 32, as described below, utilising an expander device 36 generally similar to the device 14 described above.

The ring 34 is initially generally cylindrical and comprises an relatively ductile anchoring portion 34a which carries grip bands of tungsten carbide chips 38 on its outer face. The anchoring portion 34a is welded to a portion 34b or harder material which defines the profile 30.

In use, the ring 34 is run into the tubing 32 with the expander device 36 located in the anchoring portion 34a. On reaching the desired location, the expander device rollers 40 are first extended to deform the anchoring portion 34a to a generally triangular form, such that areas of the portion 34a corresponding to the roller locations are pushed into contact with the tubing wall. Such contact prevents relative rotation of the ring 34 relative to the tubing 32. The device 40 is then rotated relative to the ring 34 and tubing 32. In a somewhat similar manner to the

tubing 12 of the first described embodiment, the anchoring portion 34a is then deformed by compressive yield and thus circumferentially extended to create an annular area of interference fit with the tubing 32. The expander device  
5 36 is then retracted, leaving the ring 34 locked in the tubing 32, as illustrated in Figure 3, and the profile 30 ready to, for example, locate and provide mounting for a valve or the like.

Reference is now made to Figures 4, 5 and 6 of the  
10 drawings, which illustrate stages in a method of providing a profile 60 in a section of tubing 62 in accordance with a second embodiment of said another aspect of the present invention. The profile 60, in the form of a bore restriction or reference point, is provided by a ring 64 of  
15 expandable metal. The ring 64 is set using an expander 66 similar to that described with reference to Figure 2 and, in the interest of brevity, the setting operation will not be described in detail. However, the ring 64 is relatively short, and indeed is shorter in length than the expander  
20 rollers 68. This allows provision of a simplified ring-mounting arrangement. In particular, the rollers 68 are profiled, each defining a central recess 70 to receive the undeformed ring 64. On reaching the desired ring location, the rollers 68 are actuated and deform the ring 64 to  
25 engage the tubing 62, and the expander 66 is then rotated relative to the ring 64 and the tubing 62 to progressively deform the ring 64 to create the desired interference fit with the tubing 62. The rollers 68 are then retracted, and

the expander 66 retrieved from the tubing 62.

Reference is now made to Figure 7 of the drawings, which is a schematic sectional view of a stage in a method of cutting tubing 50 in accordance with an embodiment of a further aspect of the present invention. The method  
5 utilises a cutter 52 of similar form to the expanders 14, 36 described above, other than the provision of a more pronounced and hardened rib 54 on each roller 56.

In use, the cutter 52 is run into the tubing to the  
10 desired location and energised, by application of fluid pressure via the supporting tool string 58, and simultaneously rotated. This extends the rollers 56 and urges the ribs 54 into rolling contact with the tubing 50. The high pressure forces created at the small area contact  
15 between the ribs 54 and the tubing 50 result in compressive yield of the tubing 50 and a localised reduction in tubing wall thickness. The progressive reduction in the wall thickness eventually results in the tubing being severed.

The behaviour of the material of the tubing 50 subject  
20 to compressive plastic deformation may vary depending on the tubing location. Where the tubing 50 is constrained, for example within an outer tubing, and the tubing diameter is not free to increase, the material of the tubing, typically steel, will flow away from the area subject to  
25 highest pressure. With appropriate roller configuration, it is therefore possible to cut inner tubing located within a larger diameter outer tubing, or tubing located within a device or tool.

As will be apparent to those of skill in the art, this ability to cut tubing downhole has many applications.

It will further be apparent to those of skill in the art that the above described embodiments are merely  
5 exemplary of the various aspects of the present invention and that various modifications and improvements may be made thereto without departing from the scope of the invention.

**CLAIMS:**

1. A method of forming a profile in a section of tubing,  
the method comprising:  
providing an expander device having at least one  
5 radially extendable expander member;  
positioning the device at a predetermined location in  
a section of tubing; and  
extending the member to deform the tubing at said  
location to create a profile therein.
- 10 2. The method of claim 1, wherein the profile is in the  
form of at least one annular recess.
3. The method of claim 1 or 2, wherein the tubing is  
deformed by rolling expansion, an expander member being  
rotated within the tubing with a face in rolling contact  
15 with an internal face of the tubing.
4. The method of claim 1, 2 or 3, wherein the tubing is  
deformed by compressive plastic deformation, producing a  
localised reduction in wall thickness and a subsequent  
increase in tubing diameter.
- 20 5. The method of claim 1, 2, 3 or 4, wherein the tubing  
is deformed by compressive plastic deformation, producing  
flow of wall material to create the profile.

6. The method of any of the preceding claims, wherein the expander member is in the form of a roller.
7. The method of claim 6, wherein the roller defines a raised circumferential profile to provide a high pressure contact area and to create a profile in the tubing of a predetermined form.
8. The method of claim 7, wherein the expander member is extended by application of fluid pressure.
9. The method of claim 8, wherein a plurality of radially extendable expander members are provided.
10. The method of any of the preceding claims, wherein the expander member is run into the tubing on a running string.
11. The method of any of the preceding claims, wherein expander is rotated to create the profile.
12. A method of providing a profile in a section of tubing, the method comprising:
- providing a ring of deformable material;
  - providing an expander device having at least one radially extendable member;
  - positioning the ring and the device at a predetermined location in a section of tubing; and



15

extending the member to deform the ring such that the ring engages the tubing at said location to provide a profile therein.

5 13. The method of claim 12, wherein the ring is preformed to define a predetermined profile.

14. The method of claim 13 or 14, wherein the ring and the expander device are run into the tubing together.

15. The method of claim 12, 13 or 14, wherein the ring is deformed to create an interference fit with the tubing.

10 16. The method of claim 15, wherein the ring is deformed to increase the diameter of a section of the ring.

15 17. The method of claim 16, wherein the ring is deformed at least partially by rolling expansion, an expander member being rotated within the ring with a face in rolling contact with an internal face of the ring.

20 18. The method of any of claims 12 to 17, wherein the ring is at least partially deformed by compressive plastic deformation producing, a localised reduction in wall thickness resulting in a subsequent increase in ring diameter.

19. Apparatus for providing a profile in a section of

tubing, the apparatus comprising: a ring of deformable material; and an expander device having at least one radially extendable member, the device being locatable within the ring and the member being extendable to deform the ring into engagement with surrounding tubing to create a profile therein.

20. The apparatus of claim 19, wherein ring is preformed to define a predetermined profile.

21. The apparatus of claim 19 or 20, wherein the ring comprises a relatively ductile portion coupled to a relatively inflexible portion.

22. The apparatus of claim 19, 20 or 21, wherein the ring carries grip banding on an outer surface to facilitate secure location relative to the tubing.

23. The apparatus of claim 22, wherein the grip banding comprises relatively hard elements.

24. The apparatus of any of claims 19 to 23, wherein the expander member is in the form of a roller.

25. The apparatus of any of claims 19 to 24, wherein the expander member is extendable by application of fluid pressure.

26. The apparatus of any of claims 19 to 25, wherein the expander device comprises a plurality of radially extendable expander members.

5 27. The apparatus of any of claims 19 to 26, wherein the expander device is adapted to be selectively rotatable relative to the ring.

28. The apparatus of any of claims 19 to 27, wherein the expander member is profiled to engage the ring and permit the ring to be run into the tubing on the expander.

10 29. A method of providing a profile in a section of tubing, the method comprising deforming a ring of material by rolling expansion within a section of tubing such that the ring engages the tubing at said location to create a profile therein.

15 30. A method of cutting a section of tubing, the method comprising:

providing a cutting device having at least one radially extendable rolling member defining a raised circumferential portion;

20 positioning the device at a predetermined location in a section of tubing;

extending the member to contact the tubing at said location and rotating the device to deform the tubing, the degree of deformation being such that the tubing is cut at

said location.

31. The method of claim 30, wherein the cutting device is provided with a plurality of rolling members, which progressively compress the tubing wall and reduce the wall  
5 thickness thereof.

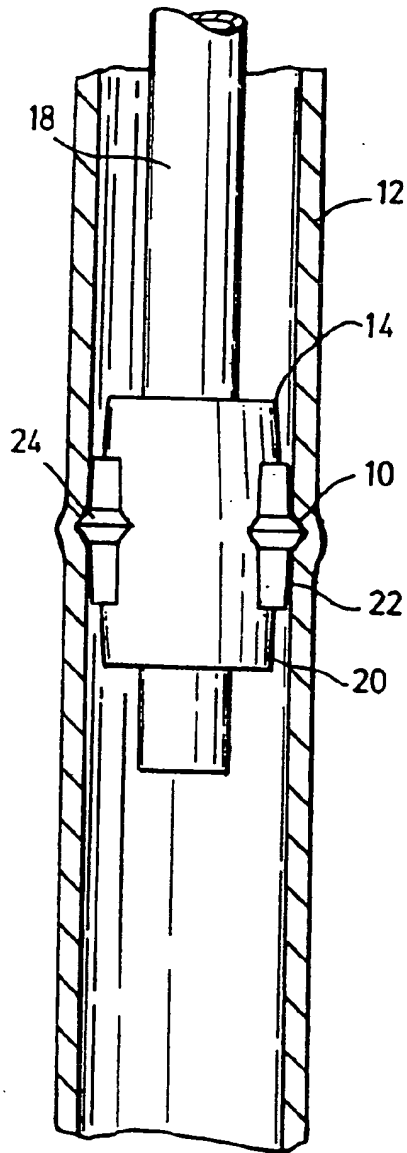


Fig. 1

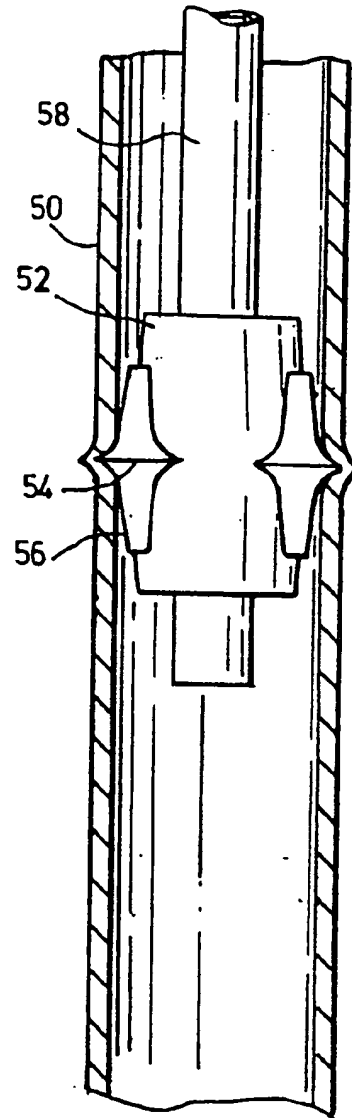


Fig. 7

2/3

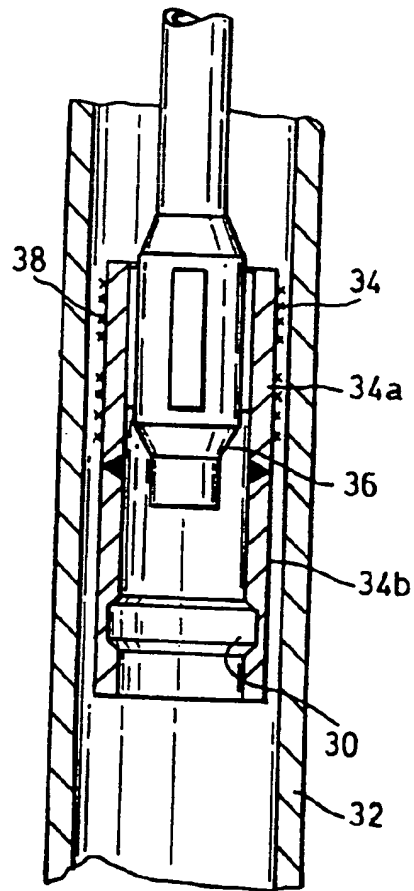


Fig. 2

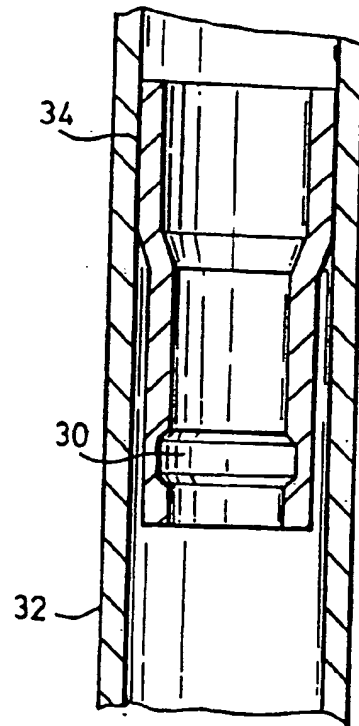
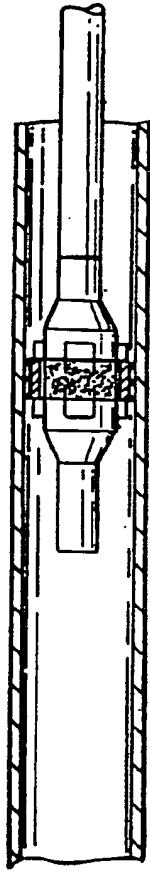


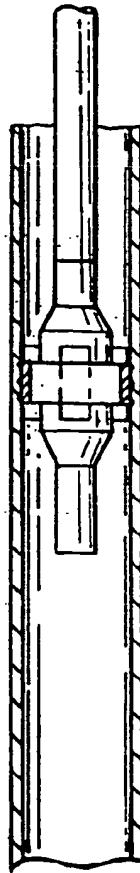
Fig. 3

3/3



RUNNING IN

Fig. 4



SETTING

Fig. 5



PULLING OUT

Fig. 6

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☐ **BLACK BORDERS**

☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

☐ **FADED TEXT OR DRAWING**

☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**

☐ **SKEWED/SLANTED IMAGES**

☒ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**

☐ **GRAY SCALE DOCUMENTS**

☒ **LINES OR MARKS ON ORIGINAL DOCUMENT**

☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**